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European Journal of Protistology 59 (2017) 34–49

European Journal of PROTISTOLOGY

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Morphological descriptions of five scuticociliates including one new species of *Falcicyclidium*

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Received 14 April 2016; received in revised form 7 March 2017; accepted 9 March 2017
Available online 16 March 2017

Abstract

Five scuticociliates, collected from China, were morphologically studied using standard methods One represents a new member of the genus *Falcicyclidium*, *F. citriforme* nov. spec., which can be recognised mainly by a combination of the following characters: usually two macronuclear nodules, buccal field about half of body length, ten somatic kineties, about 22 kinetal units in somatic kinety 1 and n, and excretory pore near posterior end of somatic kinety n. A redescription for *Biggaria bermudensis* was provided to include the feature of scutica and argyrome based on new isolate, and variations between different isolates were also discussed. The new population of *Sathrophilus holtae* differs from the type population by two postoral kineties and fewer kinetal units in the scutica. Its stomatogenesis belongs to the scuticobuccokinetal type, which shows similarities with *Dexiotricha* among loxocephalids. Morphometric data and brief descriptions were supplied for another two species, i.e., *Protocyclidium citrullus* and *Cyclidium varibonneti*.

Keywords: *Biggaria*; *Falcicyclidium citriforme* nov. spec; Morphology; *Sathrophilus*; Stomatogenesis

Introduction

Scuticociliates are one of the most abundant ciliate groups in various biotopes worldwide, and play a vital role in the microbial food web (Buosi et al. 2011; Durán-Ramírez et al. 2015; Foissner et al. 2002, 2003; Rossi et al. 2015; Song et al. 2009). They also exist as symbionts, or even pathogens, of aquatic animals (Jones et al. 2010; Lobban et al. 2011; Xu et al. 2015). In the past two decades, an extensive body of work on the ciliate fauna in Chinese coastal waters has revealed extremely high diversity of this group of organisms (e.g. Fan et al. 2011a,b; Gong and Song 2008; Liu et al. 2016; Long et al. 2006, 2007a,b; Miao et al. 2010; Pan et al. 2016, 2011, 2015a,b,c; Song 2000; Song et al. 2003; Wang et al. 2008a,b,c, 2009; Xu et al. 2015). Meanwhile, those species that lack detailed documentation, especially pleuronematids and philasterids have been re-investigated

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http://dx.doi.org/10.1016/j.ejop.2017.03.003
0932-4739/

using standard methods in order to circumscribe morphospecies (e.g. Fan et al. 2011b; Song and Wilbert 2000, 2002; Song et al. 2002a,b; Wang 2009), and analyses based on morphogenesis and molecular phylogeny have been increasingly undertaken to answer the systematic questions within this subclass (e.g. Gao et al. 2012, 2013, 2014; Ma and Song 2003; Ma et al. 2003, 2006; Pan et al. 2011; Song et al. 2005; Zhang et al. 2011).

Cyclidium-like genera, e.g., *Cyclidium* Müller, 1773, *Falcicyclidium* Fan et al., 2011, *Protocyclidium* Alekperov, 1993, and *Acucyclidium* Gao et al., 2014, share similar ciliary pattern, but meanwhile, differences in both oral apparatus and living morphology are gradually recognised and raised as species- or genera-dependent as taxonomy and phylogenetic work are accumulated (Fan et al. 2011a,b; Foissner et al. 2002; Gao et al. 2014). Hence, careful reinvestigation of known species may contribute equally as exploring new taxa in understanding the species diversity of this group (Fan et al. 2011b; Foissner et al. 1994; Song 2000).

Sathrophilus Corliss, 1960 was redefined by Long et al. (2007b), and contains about 15 nominal species so far. Infraciliature data of nearly half of them are available (Fan et al. 2010). The morphogenetic information, however, is limited, because only few dividing stages of *S. holtae* were documented (Long et al. 2007b). This resulted in the confusion related to its systematic position (Zhang et al. 2011).

The genus *Biggaria* was first established by Kahl (1934), but it was nomen nudum until Aescht (2001) fixed the type species, *B. bermudensis*. The type species had been described frequently, but sufficient redescription based on modern method is still lacking (Berger 1964; Biggar and Wenrich 1932; Lucas 1940; Nie 1934; Powers 1933, 1935).

As a part of ciliates faunistic surveys in coastal water of China, the present study documents five scuticociliates, including one new *Falcicyclidium* species. Morphological traits from live specimen, morphometric data, and ecological features are supplied.

Material and Methods

Specimens of *Falcicyclidium citriforme* nov. spec. and *Sathrophilus holtae* were collected from sandy beaches in China (Table 1). Fine sand containing seawater was taken directly from the surface of sediments and ciliates were flushed out with the help of a strainer. *Protocyclidium citrullus* and *Cyclidium varibonneti* were collected from seawater, which was taken directly with a 500 ml jar. Ciliates became abundant several days after rice grains were added to the raw culture to enrich bacterial food. *Biggaria bermudensis* was isolated from the digestive tracts of sea urchins, *Hemicentrotus pulcherrimus*. The host was dissected and then its mantle was flooded with filtered, ciliate-free marine water. For details of the sampling information see Table 1.

Cells were isolated with a fine pipette under a dissection microscope and were then observed in vivo using differential interference contrast microscopy. The protargol (Wilbert 1975) and Chatton-Lwoff silver-nitrate staining methods (Song and Wilbert 1995) were used to reveal the infraciliature and argyrome (silverline pattern), respectively. Drawings of stained specimens were made with the help of a camera lucida. Measurements were made under 100–1250× magnification. Terminology and classification mainly follow Corliss (1979) and Lynn (2008), respectively.

Results and Discussion

Subclass Scuticociliatia Small, 1967
Order Pleuronematida Fauré-Fremiet in Corliss, 1956
Family Ctedoctematidae Small and Lynn, 1985
Falcicyclidium Fan et al., 2011
Falcicyclidium citriforme nov. spec. (Figs 1 **A–H,** 2 **A–N,** Table 2)

Synonyms. *Falcicyclidium plouneouri* (Dragesco, 1963) Gao et al., 2014 (misidentification and incorrect combination with *Falcicyclidium*; see discussion); *Cyclidium plouneouri* Dragesco, 1963 sensu Wang (2009) (misidentification; see discussion).

Diagnosis. Marine *Falcicyclidium*, in vivo about 50 × 30 μm, lemon-shaped in ventral view, dorso-ventrally flattened about 2:1. Buccal field occupying half body length. 10 somatic kineties, kinety 1 with about 22 kinetal units, kinety n with about 22 kinetal units and posteriorly shortened. Approximately nine caudal cilia. Usually two macronuclear nodules in anterior half. Contractile vacuole posteriorly positioned on ventral side and with excretory pore posterior to somatic kinety n.

Etymology. The species-group name *citriforme* (Latin adjective, lemon-shaped) recalls the body shape of this species.

Type locality. Sandy beach in Qingdao, China (36°03′18″N; 120°20′37″E; details see Table 1).

Ecological features. This species probably typically inhabits sandy sediments. It was found in all surveyed sandy beaches in Qingdao near the Yellow Sea. It was also collected once from a sandy beach in Daya Bay, Huizhou, southern China.

Deposition of type slides. The protargol-stained slide containing the holotype specimen (Figs 1 G, H, 2 F, G; registration number: wyg-20051130-01) and two paratype slides with silver nitrate-stained specimens (registration numbers: wyg-20051130-02, wyg-20051130-03) had been deposited in the Laboratory of Protozoology, Ocean University of China, Qingdao, China. The holotype has been marked by an ink circle.

Description based on Qingdao population. Living cells about 40–60 × 20–40 μm in size; lemon-shaped when viewed ventrally (Figs 1 A, 2 A–C), dorsoventrally flattened about 2:1; anterior end truncated, posterior end broadly rounded (Figs 1 A, B, 2 D, E). Buccal field prominent,